**Student Name: Kaiwen Suo**

**Student ID: 1005764816**

## 1. Introduction

This study aims to analyze MRI data obtained from patients both with and without dementia. To identify patterns of brain alterations and their interactions with intracranial volume parameters, mixed-effects ANOVA is employed.

This report using the data from "INF2178_A4_data.csv" to analyze the patterns of brain alterations and interactions with intracranial volume parameters. The dataset is prepared, cleaned, and organized for further using.

This research focus on two issues and apply them as directions to organize and analyze the relationship:

**Research Question 1:** Does the brain structure change significantly over time of people with dementia compared to people without dementia?

**Research Question 2:** How does dementia status impact the estimated total intracranial volume in different groups across different visits?

## 2. Data preparation

Dataset contains 16 columns and 294 rows. By analyzing the data structure, we include useful data in our research. Below is the describe of each variable and their structure:

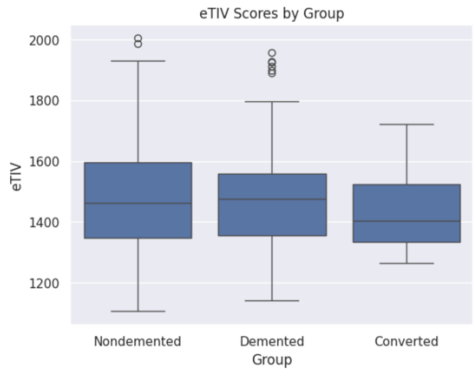
1. **Visit:** First or Second Visit
2. **Group:** Nondemented, Demented, or Converted
3. **eTIV:** Estimated total intracranial volume
4. **nWBV:** Normalized whole brain volume
5. **Subject ID:** Unique patient ID

***Missing value examine:***

After examining the dataset, 'SES' and 'MMSE' have missing value. Drop missing value directly.

## 3. Exploratory Data Analysis (EDA)

**Figure 1** shows eTIV distributions for all groups. Nondemented groups have higher median eTIV, suggesting larger brain volumes. The Converted group shows a narrower interquartile range, implying less variability. The Demented group's median eTIV is the lowest, indicating smaller brain volumes. **Figure 2** compares normalized whole brain volumes (nWBV) across Nondemented, Demented, and Converted groups. The median nWBV is highest for Nondemented and lowest for Demented.



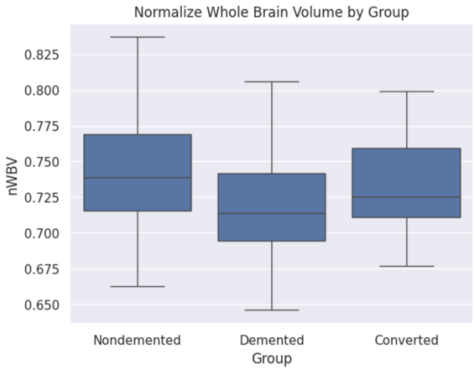




*Figure 1: eTIV Scores by Group*

*Figure 2: Normalize Whole Brain Volume by group*

In below table, the **eTIV** section of the table indicates that Nondemented groups start with the highest brain volume, with a slight decrease by the second visit, while Demented subjects consistently show the lowest volumes. Standard deviations indicates similar variability across visits and groups. **nWBV** with the highest initial volumes in Nondemented subjects decreasing slightly in the second visit, and the lowest volumes founded in Demented subjects, also with minimal changes over time. Variability is consistent across all groups and visits.

| **eTIV** | | **mean** | std | **nWBV** | | **mean** | **std** |
|---|---|---|---|---|---|---|---|
| **Visit** | **Group** | | | **Visit** | **Group** | | |
| **1** | Converted | 0.74 | 0.03 | **1** | Converted | 0.74 | 0.03 |
| **1** | Demented | 0.72 | 0.03 | **1** | Demented | 0.72 | 0.03 |
| **1** | Nondemented | 0.75 | 0.04 | **1** | Nondemented | 0.75 | 0.04 |
| **2** | Converted | 0.73 | 0.04 | **2** | Converted | 0.73 | 0.04 |
| **2** | Demented | 0.71 | 0.03 | **2** | Demented | 0.71 | 0.03 |
| **2** | Nondemented | 0.74 | 0.04 | **2** | Nondemented | 0.74 | 0.04 |

*Table 1: eTIV and nWBV summary*

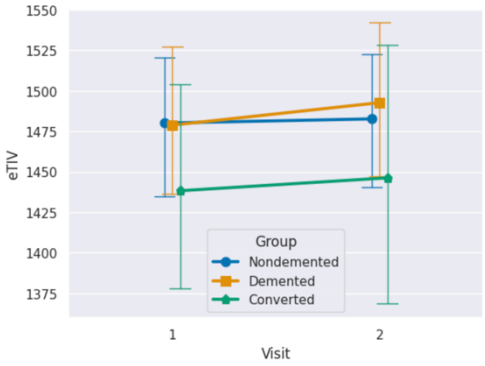
## 4. eTIV Mixed-Effect ANOVA

| **Source** | **SS** | **DF1** | **DF2** | **MS** | **F** | **p-unc** | **np2** | **eps** |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Group | 38580.795 | 2 | 134 | 19290.398 | 0.306 | 0.737 | 0.005 | nan |
| Visit | 5073.142 | 1 | 134 | 5073.142 | 8.139 | 0.005 | 0.057 | 1 |
| Interaction | 953.089 | 2 | 134 | 476.545 | 0.765 | 0.468 | 0.011 | nan |

*Table 2: Mixed-Effect ANOVA table for eTIV*

The Mixed-Effect ANOVA table of eTIV shows **"Visit"** has a significant effect (p=0.005) on the dependent variable, whereas **"Group"** (p=0.737) and the **interaction** between "Group" and "Visit" (p=0.468) do not. Post Hoc test results indicate a significant decrease from Visit 1 to Visit 2 (p=0.005) with a small effect size.




The Pointplot of eTIV shows changes in eTIV for all groups over two visits, with all groups demonstrating a slight decrease from Visit 1 to Visit 2, and error bars indicating overlapping variances between groups.

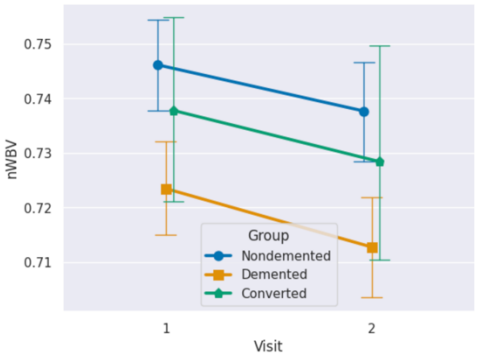
*Figure 3: Pointplot for change in eTIV across groups*

## 5. nWBV mixed-effect ANOVA

| **Source** | **SS** | **DF1** | **DF2** | **MS** | **F** | **p-unc** | **np2** | **eps** |
|---|---|---|---|---|---|---|---|---|
| Group | 0.033 | 2 | 134 | 0.017 | 6.384 | 0.002 | 0.087 | nan |
| Visit | 0.006 | 1 | 134 | 0.006 | 89.376 | 0 | 0.4 | 1 |
| Interaction | 0 | 2 | 134 | 0 | 1.63 | 0.2 | 0.024 | nan |

*Table 3: Mixed-Effect ANOVA table for nWBV*

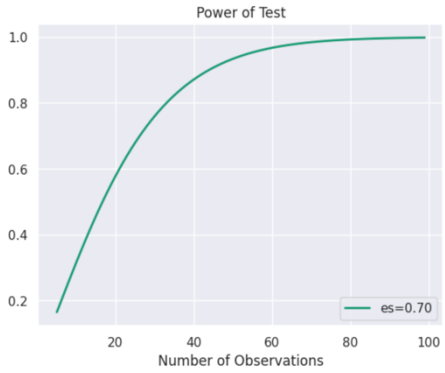
The table shows Mixed-Effect ANOVA of nWBV . **"Group"** having an F-value of 6.384 (p=0.002) indicating a statistically significant effect with a small to medium effect size. **"Visit"** shows a very significant effect (p<0.001) with a large effect size. The **interaction** is not significant (p=0.200), suggesting no significant interaction effect between group and visit. Post hoc test shows significant difference between Visits 1 and 2 (p<0.001) with a small to medium effect size .




This Pointplot shows a decrease in nWBV from Visit 1 to Visit 2 for all groups, with the Demented group showing the largest decreased.

*Figure 4: Pointplot for change in nWBV across groups*

## 6. Statisctial Power Analysis




The power curve on the graph increases sharply with the number of observations, indicating higher test sensitivity, and peak near perfect power (1.0) at around 80 observations for an effect size of 0.70. With the actual sample sizes around 45, it indicates increasing sample size will be efficency for further study.

*Figure 5: Power plot for t-test*

## 7. Assumption Check

**Model 1:** The Shapiro-Wilk tests show the residuals are not normally distributed ($p < 0.05$ for all groups), while Levene's test indicates homogeneity of variances is hold ($p = 0.2689$).

**Model 2:** Shapiro-Wilk tests yield p-values of 0.3170 for Nondemented, 0.3659 for Demented, and 0.3580 for Converted, indicating normal distribution of residuals for all groups. Levene's test for homogeneity of variances shows a p-value of 0.6138, suggesting equal variances across groups.

## 8. Conclusion

This study found that normalized whole brain volume decreased over time in all groups, while estimated total intracranial volume remained stable. These results enhance our understanding of how dementia affects brain structure. Further study should increase the sample size for more efficiency.